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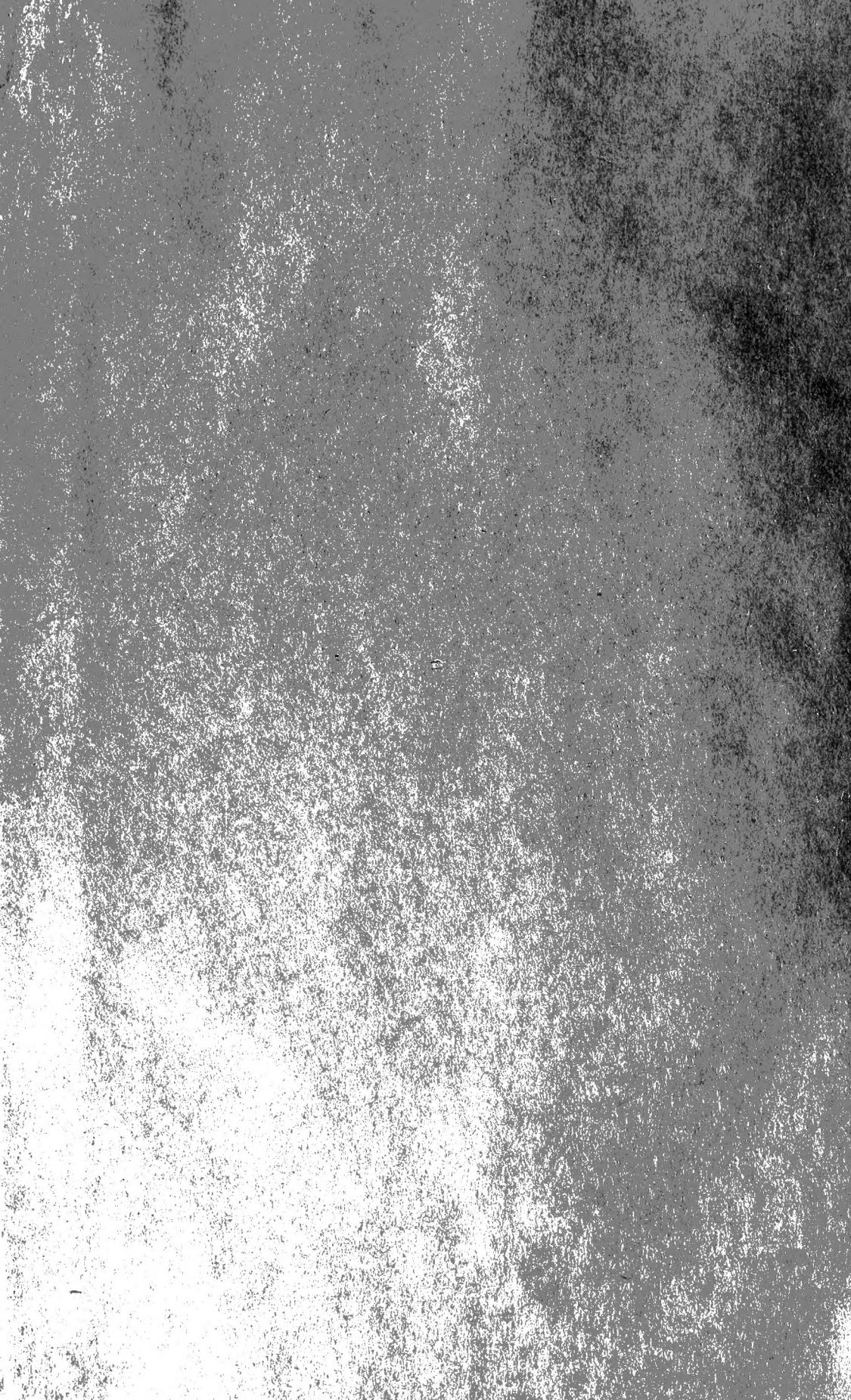
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# ILLINOIS BIOLOGICAL MONOGRAPHS

VOLUME XIII

PUBLISHED BY THE UNIVERSITY OF ILLINOIS

URBANA, ILLINOIS

EDITORIAL COMMITTEE

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JOHN THEODORE BUCHHOLZ  
FRED WILBUR TANNER  
CHARLES ZELENY, Chairman

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STUDIES ON SOME PROTOZOAN  
PARASITES OF FISHES OF  
ILLINOIS

WITH EIGHT PLATES

BY  
RICHARD ROKSABRO KUDO

Contribution from the Zoological Laboratory of the  
University of Illinois  
No. 450



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## INTRODUCTION AND ACKNOWLEDGMENT

This paper is divided into two parts. The first part deals with a preliminary observation made by the author from August 12 to September 11, 1930, under the auspices of the Illinois State Natural History Survey, on some parasitic Protozoa of fishes inhabiting the main water systems of the state. The second part gives the descriptions of several new species and additional information on a few already known species of Myxosporidia observed during this survey and also in the fishes which have been collected by Dr. D. H. Thompson, Zoologist of the Survey, from various parts of the state in connection with his work over a period of several years.

The author is indebted to Dr. Thompson for these materials placed at his disposal and for assistance during the month of field study. Thanks are also due to Mr. F. D. Hunt of the Survey, who was instrumental in the collection of material on the Fox River.

The specimens are deposited in the collections of the Illinois State Natural History Survey at Urbana.

## PRELIMINARY SURVEY OF PROTOZOAN PARASITES OF FISHES OF ILLINOIS

Various protozoan parasites are known to occur in fresh-water fishes. Certain ciliates, for example, *Ichthyophthirius* and *Cyclochaeta*, if present in large numbers, have been found to become the causes of epidemic diseases in fresh-water fishes. Among Mastigophora and Sarcodina are found some species which parasitize fishes, although their effect upon the host is as a rule less noticeable. A group of Sporozoa known as Myxosporidia is, however, almost exclusively parasitic in fishes (Kudo, 1920). While numerous Myxosporidia occur in organ cavities, such as the gall bladder, urinary bladder, ureter or uriniferous tubules of the kidney, they do not ordinarily seem to exercise any harmful effects upon the body of the host. On the other hand, the Myxosporidia which attack tissues of the host produce various histopathologic changes which hinder the normal functions of the organs concerned, and appear in many cases to cause the death of the host. Death is due, not only to these protozoan parasites as the primary causes, but also to secondary bacterial or fungous infections of the affected tissues. Instances are not uncommon in which infection assumes an epidemic form and so damages the fishes that they become unmarketable or unattractive to the consumer, as in the "wormy" halibut of the Pacific coast (Davis).

Histozoic Myxosporidia are most frequently found to attack the gills, integument, fins, muscles, etc., of fresh-water fishes, and when the infection is at an advanced stage, certain characteristic changes in the attacked tissues result. These changes are often recognizable by the unaided eye. When the viscera are affected, the myxosporidian infection as a rule is to be discovered only by dissection and microscopical examination. Even here an extreme hypertrophy of the infected tissue may, however, cause characteristic changes visible externally, as in the case of the silver-mouthed minnow infected by *Myxosoma grandis* (Figs. 1 and 2) or in the young tench suffering from a heavy infection by *Sphaerospora pernicialis* (Léger).

In the present survey the author's attention was directed mainly to tissue-attacking Protozoa, especially Myxosporidia. Each living, dead, or freshly "dressed" fish was examined first with the unaided eye with respect to external conditions, and when abnormalities were recognized, the latter were examined microscopically. If these bodily changes were found to be due to protozoans, the greater portion of the infected tissues or organs was preserved in either 4 per cent formol or Bouin's fluid for a more thorough study at the laboratory. Examination of coelozoic Protozoa was conducted only on a few occasions.

In this manner more than 1,300 fishes belonging to 35 species were examined. The fishes sold at fish markets or caught by fishermen were examined whenever possible, and in the case of the species which were not to be found in the market, seines or hook and line were used to collect them. Visiting fish markets was further useful, since general information about abnormalities or diseases of fishes in a particular locality was often obtained.

The results of the observations follow:

*Polyodon spathula* (paddle-fish). Fifteen fishes caught in the Mississippi River, and examined at a fish market in Davenport, Iowa, showed no histozoic protozoan infection.

*Lepisosteus osseus* (long-nosed gar). Six specimens examined at Dundee and Meredosia were apparently free from protozoan infection.

*Amia calva* (dogfish). Four fishes from the Fox River at Dundee (August 12) and two from the Illinois River at Meredosia (September 3) were examined alive and found to show no noticeable protozoan parasites.

*Dorosoma cepedianum* (hickory shad). Fifty-six fishes caught by seining in the Rock River near Sterling (August 19) were apparently free from histozoic protozoan infection.

*Argyrosomus artedi* (lake herring). About 100 "dressed" fishes examined at a fish market in Waukegan (August 14) were free from any

noticeable protozoan infection. The same was true of some 230 fishes, caught in gill nets, about twenty-two miles east of Waukegan in Lake Michigan (August 15), which were inspected on the boat as they were cleaned, although the majority were parasitized by tapeworms.

*Ictiobus bubalus* (small-mouth buffalo). Of thirty-six fishes examined at a fish market in Havana (August 28), one showed cysts of *Myxobolus ovatus* n. sp. (p. 20) in the integument. Twenty more examined at a Pekin market did not show any infection.

*Carpoides velifer* (silver carp). Of the three fishes caught in the Illinois River at Meredosia (September 3), one specimen, 7 cm. long, showed a light infection by *Myxobolus obliquus* n. sp. (p. 25).

*Catostomus commersonii* (common sucker). Eight large fishes caught in the Fox River near Dundee were free from any recognizable protozoan infection.

*C. nigricans* (hog sucker). Four fishes caught in the Fox River near Dundee (August 12 and 13) were apparently free from any protozoan infection.

*Moxostoma anisurum* (white-nosed sucker). Thirty-five fishes were seined in the Fox River near Dundee (August 12 and 13). Of these, twenty showed large isolated tumors on, or near the base of, the anal or caudal fin (Figs. 7 and 14). The tumors were covered by a reddish network which gave them a characteristic appearance. Microscopical examination revealed that the growths were due to the presence of numerous cysts of *Myxobolus congesticius* n. sp. (p. 26). Both of the two fishes caught in the same river at Carpentersville were infected by another myxosporidian, *Myxobolus gravidus* n. sp. (p. 22), which formed small cysts in the integument and fins.

*M. auriculatum* (common red-horse). Of the ten fishes obtained from the Fox River near Dundee (August 12), one was infected by a myxosporidian, *Myxobolus vastus* n. sp. (p. 21), which was represented by three conspicuous cysts located on three different scales.

*M. breviceps* (short-headed red-horse). Of the twenty-three fishes caught in the Fox River near Dundee (August 12 and 13), twelve were infected by cysts of a myxosporidian, *Myxobolus conspicuus* Kudo (p. 27), (Figs. 15 and 16). As was noted before (Kudo, 1929), these cysts were confined to the head region of the host fish.

*Cyprinus carpio* (carp). Two young carp seined in the Fox River near Carpentersville (August 14) and three caught in a creek near Rockford (August 18) were free from any noticeable protozoan parasites. The carp examined at fish markets in Depue, Peoria, Pekin,

Havana, Liverpool, and Quincy, totaling 165 in number, appeared also free from any protozoan infection.

In large reservoirs located in the vicinity of Peoria which were supplied with the water from several springs, there were noted large numbers of carp suffering from an extremely heavy infection by a parasitic ciliate, *Ichthyophthirius multifiliis*. A dozen of them were caught by a net without difficulty, since they were lying in the shallow water along the bank. The integument, the gills (Fig. 8), and the mucous membrane of the buccal cavity, all were so heavily infected by this protozoan that the entire fish appeared whitish in color. In addition, Cyclochaeta, another ciliate, and Costia, a flagellate, were found abundantly, especially in the lesions which *Ichthyophthirius* produced. As a result of the infection the fishes appeared extremely weakened. It was said that the reservoirs had had an unusual thick growth of vegetation prior to the author's visit, and this obviously had limited the activity of the fish, prevented rapid flow, and brought about a rise in temperature of the water. Undoubtedly these changes were favorable for the growth and reproduction of the ciliate at the expense of the carp, and the epidemic resulted. *Ichthyophthirius* infection has world-wide distribution, and it is not uncommon to find heavy infection in young fishes kept in small aquaria, but it is certainly remarkable that such an epidemic should occur among fully grown fishes kept in large outdoor ponds.

*Campostoma anomalum* (dough-belly). Of the eleven fishes seined in a small creek running by the state fish hatchery near Rockford (August 18), one showed in its fins small cysts (Fig. 32) of a myxosporidian, *Henneguya crassicauda* n. sp. (p. 31).

*Pimephales notatus* (blunt-nosed minnow). Of forty-two fishes seined in the Rock River near Sterling (August 19), two were infected by *Thelohanellus notatus* (Mavor) (p. 29) which formed cysts in the head and body. One fish showed golden cysts (Fig. 9) of *Myxobolus aureatus* Ward (p. 28) in the fins. Several had ectoparasitic copepods attached to the dorsal fin, which resembled, to a certain extent, myxosporidian cysts, but which quickly fell off as the fishes were brought out of the water.

*Notropis cornutus* (common shiner). Of the eighteen fishes seined in a small creek near Rockford (August 18), one exhibited a large tumor on the left side of the body just behind the head. Microscopical examination revealed that this large growth was due to an infection by a myxosporidian, *Thelohanellus notatus* (Mavor).

*Ictalurus furcatus* (blue cat). Six fishes, one of which weighed 20 pounds, examined near Brookport (September 9), were apparently free from any histozoic protozoan infections.

*I. punctatus* (channel cat). Of the twelve fishes caught in the Fox River near Dundee (August 13), two exhibited several cysts of *Henneguya exilis* Kudo in the gills (Fig. 6). Twenty-nine more were examined at a fish market in Havana (August 28), and the gills of two of them showed one and two cysts, respectively, of the same myxosporidian. Three fishes obtained from the Illinois River at Meredosia (August 30) were free from protozoan parasites.

*Ameiurus melas* (black bullhead). Two fishes collected from the Fox River at Dundee (August 13) were free from any protozoan parasites seen by external examination. The same was true of eight others inspected at a fish market in Havana (August 28).

*Esox lucius* (northern pike). Two fishes caught in the Fox River near Dundee (August 13) were free from any protozoan infection.

*Eucalia inconstans* (brook stickleback). Twenty-two specimens collected from a spring-fed pool near Rockford appeared uninfected by any cnidosporidian parasite.

*Pomoxis annularis* (white crappie). Eighteen specimens observed at Dundee, Rockford, Sterling, and Meredosia were apparently free from protozoan infections.

*P. sparoides* (black crappie). Twenty caught by fishermen in the Illinois River above Meredosia were free from any histozoic protozoan parasites. One showed growths on the tail fin which resembled closely the lymphocystis cells which had been known to occur in certain marine fishes in European waters, but which have not been recorded from any North American fish.<sup>1</sup>

*Ambloplites rupestris* (rock bass). Nine fishes collected from the Rock River at Dundee (August 12) did not show any infection by histozoic protozoans.

*Lepomis pallidus* (bluegill). Forty specimens examined at Dundee, Spring Grove, Rockford, Sterling, and Meredosia were apparently free from any protozoan infections.

*Chaenobryttus gulosus* (warmouth bass). Six fishes obtained at Meredosia from the Illinois River did not show any histozoic protozoan parasites.

*Eupomotis gibbosus* (pumpkinseed). Thirty-eight fishes caught in the Fox River near Dundee, in the Rock River near Rockford, and in the Illinois River near Meredosia, showed no noticeable protozoan parasites.

<sup>1</sup>Since that time several other species of fish were found to possess similar growths. Their study is under way and will be reported elsewhere.

*Micropterus dolomieu* (small-mouth black bass). One seined in the Fox River at Carpentersville (August 14) and eight kept in a tank at Spring Grove hatchery (August 16) did not show any abnormality which could be attributed to protozoan infection.

*M. salmoides* (large-mouth black bass). Thirty-four fishes were examined alive in the water at the hatcheries at Spring Grove, Rockford, Wyanet, and Meredosia. None showed any protozoan infection. Some individuals had diffused dark-pigmented areas on the body surface, but there was no indication that the peculiarity was due to parasitic Protozoa.

*Perca flavescens* (yellow perch). About 100 "dressed" fishes examined at a fish market in Waukegan (August 14) did not exhibit any recognizable protozoan infection. The same was true with three fishes seined in the Fox River near Dundee (August 12 and 13).

*Boleosoma nigrum* (Johnny darter). Twenty-seven fishes seined in the Fox River near Carpentersville (August 14) appeared free from any visible protozoan infection.

*Etheostoma coeruleum* (rainbow darter). Twenty fishes seined in the Fox River near Carpentersville did not show any protozoan parasites.

*E. flabellare* (fan-tailed darter). Twelve fishes caught in the Fox River near Carpentersville were free from abnormalities due to parasitic Protozoa.

*Roccus chrysops* (white bass). Nine fishes examined at Dundee, Sterling, and Meredosia did not show any protozoan infection.

*Aplodinotus grunniens* (sheepshead). Some 100 fishes were examined at a fish market in Davenport, Iowa (August 21). They had been caught in the Mississippi River in the vicinity of that city and were dead when examined. None showed any infection by histozoic Protozoa visible to the naked eye. While the fishes were being cleaned, the contents of forty gall bladders were examined microscopically, of which twenty-seven contained a few scattered spores and disporoblastic pansporoblasts of a myxosporidian, *Myxidium aplodinoti* n. sp. (p. 15), which floated in the bile. Trophozoites were completely disintegrated already. As is usually the case with a light myxosporidian infection in this organ, the bladder and the bile did not appear much different from those of a normal fish. The gall bladders of two fishes dissected and examined at a fish market in Shawneetown (September 11) were not infected by the myxosporidian. In the intestine of one fish enormous numbers of a flagellate, *Octomitus* sp., were observed.

The observations are summarized in the accompanying table.

Species of Fish	Fishes Examined	Fishes Infected	Protozoan Parasites
<i>Polyodon spathula</i> .....	15	...	
<i>Lepisosteus osseus</i> .....	6	...	
<i>Amia calva</i> .....	6	...	
<i>Dorosoma cepedianum</i> .....	56	...	
<i>Argyrosomus artedi</i> .....	330	...	
<i>Ictalurus bubalus</i> .....	56	1	<i>Myxobolus ovatus</i>
<i>Carpoides velifer</i> .....	3	1	<i>M. obliquus</i>
<i>Catostomus commersonii</i> .....	8	...	
<i>C. nigricans</i> .....	4	...	
<i>Moxostoma anisurum</i> .....	37	20	<i>M. congesticius</i>
		2	<i>M. gravidus</i>
<i>M. aureolum</i> .....	10	1	<i>M. vastus</i>
<i>M. breviceps</i> .....	23	12	<i>M. conspicuus</i>
<i>Cyprinus carpio</i> .....	182	12	<i>Ichthyophthirius multifiliis</i> <i>Cyclochaeta</i> sp. <i>Costia necatrix</i>
<i>Campostoma anomalum</i> .....	11	1	<i>Henneguya crassicauda</i>
<i>Pimephales notatus</i> .....	42	2	<i>Thelohanellus notatus</i>
		1	<i>Myxobolus aureatus</i>
<i>Notropis cornutus</i> .....	18	1	<i>Thelohanellus notatus</i>
<i>Ictalurus furcatus</i> .....	6	...	
<i>I. punctatus</i> .....	44	4	<i>Henneguya exilis</i>
<i>Ameirus melas</i> .....	10	...	
<i>Esox lucius</i> .....	2	...	
<i>Eucalia inconstans</i> .....	22	...	
<i>Pomoxis annularis</i> .....	18	...	
<i>P. sparoides</i> .....	20	...	
<i>Ambloplites rupestris</i> .....	9	...	
<i>Lepomis pallidus</i> .....	40	...	
<i>Chaenobryttus gulosus</i> .....	6	...	
<i>Eupomotis gibbosus</i> .....	38	...	
<i>Micropterus dolomieu</i> .....	9	...	
<i>M. salmoides</i> .....	34	...	
<i>Perca flavescens</i> .....	103	...	
<i>Boleosoma nigrum</i> .....	27	...	
<i>Etheostoma coeruleum</i> .....	20	...	
<i>E. flabellare</i> .....	12	...	
<i>Roccus chrysops</i> .....	9	...	
<i>Aplochitonotus grunniens</i> .....	100	...	
Gall bladder.....	42	27	<i>Myxidium aplochitonoti</i>
Intestine.....	2	1	<i>Octomitus</i> sp.

Thus the present survey shows that the fishes belonging to three families were more or less frequent hosts to parasitic Protozoa. Of the three species belonging to the family Siluridae (the catfishes), the gills of about 9 per cent of *Ictalurus punctatus* examined were infected by a myxosporidian, *Henneguya exilis*. On the other hand, each of the four species belonging to the family Cyprinidae (the minnows and carp) was host to a protozoan parasite. The observation made in the vicinity of Peoria indicates that a heavy *Ichthyophthirius* infection in adult fishes kept in a large outdoor reservoir may follow certain changes in the physical conditions of the water. A myxosporidian parasite was observed in each

of the other three species of fish in either the fins or integument. About 2 per cent of *Pimephales notatus* were parasitized by *Myxobolus aureatus*, and *Thelohanellus notatus* was observed in about 5 per cent of both *Pimephales notatus* and *Notropis cornutus* examined, while *Henneguya crassicauda* was found in one out of 11 *Campostoma anomalum*.

The myxosporidian infection was, however, quite common in five out of seven species studied belonging to the family Catostomidae (the suckers). Each of four species harbored a myxosporidian, while the fifth was host to two species of Myxosporidia. The occurrence of *Myxobolus congesticus* in 20 out of 37 *Moxostoma anisurum* and of *Myxobolus conspicuus* in 12 out of 23 *Moxostoma breviceps* would indicate that these two myxosporidians were very common parasites in these fishes in the Fox River at the time of examination. Aside from *Myxobolus obliquus* which was observed in the body muscle fiber of *Carpoides velifer*, the five species of Myxosporidia attacked either fins or integument of the host body.

Since the myxosporidian infections were in no case severe and were confined in almost all the fishes to the extremities or superficial portions of the body, it did not appear that they brought about any harmful effects. It must, however, be remembered that lesions produced by them become often the foci of secondary fungous or bacterial infections which may result in the death of the host. The solution of various problems brought out through the present survey awaits more intensive studies.

#### DESCRIPTIONS OF THE SPECIES OF MYXOSPORIDIA FOUND PARASITIC IN FISHES OF ILLINOIS

In the following pages are given descriptions of several new species and additional information on a few already known species of Myxosporidia which were found parasitic in some of the fishes inhabiting the waters of Illinois. As to the former records of the Myxosporidia reported from Illinois, the reader is referred to Kudo (1920, 1920a, and 1929).

Each species described below was compared carefully as far as possible with the known species of the genus (Kudo, 1933) to which it belongs with respect to the characters of both the spore form and the vegetative form. The spores of one species were studied in life. Those of all other species were examined in material preserved in formol (4 per cent), which would give somewhat smaller dimensions than fresh spores (Kudo, 1921). To facilitate future comparison, dimensions of preserved, unstained spores as viewed in water suspension, are given.

*Myxidium aplodinoti* n. sp.

(Figs. 35-38)

**HABITAT.**—In the gall bladder of the sheepshead, *Aplodinotus grunniens*. From the Mississippi River in the vicinity of Davenport, Iowa (August 21, 1930). The host organ of twenty-seven out of forty fishes brought into a market exhibited a light infection by this myxosporidian.

**VEGETATIVE FORM.**—The host fish had been dead for some time when examined, and the vegetative forms had apparently disintegrated. Isolated spores and a few disporoblastic pansporoblasts were noted. This myxosporidian is probably polysporous.

**SPORE.**—Fusiform. The shell-valves are slightly asymmetrical; each with seven to nine striae which run parallel to the sutural line. Extremities are either bluntly or sharply pointed. Sutural line distinct though delicate. The polar capsules are broadly pyriform or subspherical. The sporoplasm is finely granulated and contains two nuclei. Dimensions of fresh spores: length 11-12  $\mu$ , width and thickness 5-6  $\mu$ , polar capsules 4-5  $\mu$  by 3-3.5  $\mu$ .

*Myxosoma grandis* n. sp.

(Figs. 1, 2, 17, and 39-42)

**HABITAT.**—In the liver of the silver-mouthed minnow, *Ericymba buccata*. The five infected fishes, measuring from 5 to 10 cm. long, were collected from the Salt Fork, a tributary of the Vermilion River, in the vicinity of Rantoul and Thomasboro (July and August, 1928, and November, 1929). All were preserved in formol when examined.

**VEGETATIVE FORM.**—As far as can be determined the myxosporidian was present in the liver only, other organs such as the heart, kidneys, intestine, etc., being free from the parasite. These fishes, unlike healthy ones, showed a great distension of the body below the pectoral fins (Fig. 1), a condition which was found to be due to an enormously enlarged liver. This organ not only pushed aside other organs of the body cavity, but forced the abdominal wall to distend to such an extent that a characteristic deformity resulted; in one fish the abdominal wall was ruptured along the median ventral line, no doubt because of the extreme enlargement of the liver which measured 10 by 10 mm. None of the infected fish was observed alive, but it is not difficult to see the fatal outcome of such an infection upon the host fish.

Viewed in section preparations, the host organ was heavily loaded with an enormous number of vegetative forms, varying in diameter from 50 to 250  $\mu$ . The majority contained highly reticulated cytoplasm, in which were located mature spores, and were somewhat angular in outline

due to the mechanical pressure received from adjacent parasites. Each vegetative form was completely surrounded by what seemed to be highly flattened cells of the host's tissue. Younger individuals contained less reticulated cytoplasm and were grouped here and there among the more numerous mature forms. They were compactly filled with characteristic nuclei and developing pansporoblasts and measured from 30 to 100  $\mu$  in the largest diameter. The pansporoblast is typically disporoblastic. Polysporous.

**SPORE.**—Ellipsoidal with bluntly drawn-out anterior, and broadly rounded posterior end in front view; pyriform in side view; lenticular in end view. The shell-valves are symmetrical, and the sutural ridge is broad. Five to ten triangular markings are observable along the posterior half of the shell in the majority of spores. The two polar capsules are elongated, pyriform, and convergent. The sporoplasm is comparatively large, uniformly granulated, and does not contain any iodinophilous vacuole. When stained, two vesicular nuclei become distinctly visible. Dimensions of spores: length 15-16  $\mu$ , breadth 9-11  $\mu$ , thickness 6-8  $\mu$ , polar capsules 6-7  $\mu$  by 2.5-3  $\mu$ .

*Myxosoma procerum* n. sp.

(Figs. 3, 18, and 43-46)

**HABITAT.**—In the integument of the trout-perch, *Percopsis guttatus*. From the Illinois River at Meredosia, June 10, 1928, and Quiver Lake, Havana, January, 1931. A single fish 6 cm. long from Meredosia showed numerous small rounded cysts in the integument and the caudal fin. These cysts were scattered over the entire body surface but were more abundant on both sides of the posterior region. The cysts appeared whitish in formol and measured about 0.5 to 1.5 mm. in diameter. Section preparations showed that the cysts were located in the connective tissue directly below the scales. One or two to several cysts were found under a single scale.

Six fishes from the latter locality, on the other hand, showed smaller numbers of cysts which, however, were much larger and more conspicuous and were distributed on the sides of the body or at the base of fins, a few being noted in the head. The fishes which measured from 6.5 to 7 cm. in length, harbored 4, 4, 5, 7, 10, and 24 cysts, respectively. These cysts, like those described above, were whitish in formol and were easily recognized with the naked eye. In surface view they were irregularly rounded to spherical in outline, 1 to 2.5 mm. in their longest diameters; but hemispherical in side view, extending 0.5 to 1 mm. above the level of the body surface. The seat of infection was similar to that which was found in the fish from the first locality.

VEGETATIVE FORM.—Viewed from the surface, the cysts are more or less circular, but somewhat flattened as noted in cross-section of the host's integument, measuring 155 by 80  $\mu$  up to 960 by 260  $\mu$ . Each cyst is surrounded by a relatively thick envelope composed of the connective tissue of the host. There is a zone, about 10  $\mu$  thick, of finely granulated cytoplasm in the peripheral part. Toward the center enormous numbers of nuclei, generative cells, disporoblastic pansporoblasts, and spores occur in the reticulated cytoplasm. Polysporous.

SPORE.—Elongated ellipsoid in front view; lenticular in side view. Shell is relatively thin; shell-valves are symmetrical. The sutural ridge is broad, but sutural line indistinct. Two polar capsules are equally large and elongate pyriform. The sporoplasm is either granulated or somewhat vacuolated, but does not possess any iodinophile vacuole. When stained, two vesicular nuclei become visible; they do not show any endosome. Dimensions of spores: length 15-17  $\mu$ , breadth 6.5-7  $\mu$ , thickness 5-6  $\mu$ , polar capsules 7-9  $\mu$  by 1.5-2  $\mu$ .

*Myxosoma robustum* n. sp.

(Figs. 4, 19, and 47-50)

HABITAT.—In the connective tissue of the integument of the common shiner, *Notropis cornutus*. Rock River near Newbury (August 20, 1926). A single formol specimen, 5.5 cm. long, showed a large tumor on the left side of the body behind the operculum. It was irregularly rounded, measuring 1.3 cm. in the largest diameter, protruding about 3 mm. above the general level of the body surface and projecting some 4 mm. into the body cavity.

VEGETATIVE FORM.—The tumor was due to the presence of an enormous number of comparatively small trophozoites situated in the connective tissue between the epidermis and the body musculature. These trophozoites are spherical or oval in shape and measure from 20 to 50  $\mu$  (exceptionally up to 150  $\mu$ ) in diameter. There are extremely large numbers of blood vessels of various dimensions penetrating through the entire group of the parasites. It is presumed that in life the tumor was quite reddish in color, judging from these blood vessels present within it. Each trophozoite was densely filled with numerous nuclei, generative cells, disporoblastic pansporoblasts, and spores. Polysporous.

SPORE.—Ellipsoidal in front view; fusiform in side view. The shell is comparatively thick and shows in the front view five to eight folds along the posterior margin. Two polar capsules are elongated pyriform and convergent. The sporoplasm occupies about one-half of the intrasporal space. It contains no iodinophile vacuole, but when stained shows

two nuclei, each with a centrally located endosome. Dimensions of spores: length 14-16  $\mu$ , breadth 10-11  $\mu$ , thickness 7-8  $\mu$ , polar capsules 6.5-7.5  $\mu$  by 2.5  $\mu$ .

*Myxosoma bibullatum* n. sp.

(Figs. 21 and 51-54)

**HABITAT.**—In the integument of the sucker, *Catostomus commersonii*, collected from the Rock River near Beloit (May 3, 1927). The fish, 5.5 cm. long, showed a hemispherical tumor on the ventral side close to the left pectoral fin. It measured 1.25 mm. in diameter.

**VEGETATIVE FORM.**—The tumor contained a single cyst situated in the subepithelial connective tissue. It was nearly spherical and was filled with developing and mature spores. The pansporoblast is disporoblastic. Polysporous.

**SPORE.**—Oval in front view; lenticular with somewhat drawn-out ends in side and end views. The shell is relatively thick, and both the sutural ridge and line are distinct. Two or rarely three radiating thickenings on the shell give a characteristic appearance to the spore. These thickenings are seemingly due to prolonged existence of the two unusually large valve cell nuclei (Figs. 21 and 53). Two polar capsules are broadly pyriform with often a long drawn-out duct. The sporoplasm is large and possesses no iodinophile vacuole. When stained, it shows two vesicular nuclei, each containing an endosome and numerous peripheral chromatin granules. Dimensions of spores: length 14-15  $\mu$ , breadth 11.5-12.5  $\mu$ , thickness 6-7.5  $\mu$ , polar capsules 7 by 3.5  $\mu$ .

*Myxobolus squamosus* n. sp.

(Figs. 5 and 55-63)

**HABITAT.**—In the connective tissue below the scales of the river chub, *Hybopsis kentuckiensis*. From the Sangamon River near Dewey (August 12, 1928). Two infected fishes were preserved in formol.

**VEGETATIVE FORM.**—This myxosporidian produces conspicuous cysts in the corium, directly below the scales. These cysts are distinctly contoured, vary in form from circular to rectangular, and are confined within the outer half of the infected scales. When an infected scale was taken from the host fish, the entire cyst was also removed. One fish, 8.6 cm. long, harbored 22 and 18 cysts on the left and right sides, respectively, while the other fish, 9 cm. long, showed 2 and 9 cysts on the corresponding sides. The cysts were distributed over the entire body with the exception of the head and fins. Preserved in formol, they were milky white and varied from 0.8 to 2 mm. in the largest diameter. In section preparations it was noted that the cysts were greatly flattened. The highly re-

ticulated cytoplasm contained numerous nuclei, developing pansporoblasts which were disporoblastic, and mature spores. Polysporous.

**SPORE.**—Circular or subcircular in front view; lenticular in side or end view. Two pyriform polar capsules are convergent at the anterior end where there occurs a small intercapsular projection. The sporoplasm occupies the posterior portion of the spore and shows a large conspicuous iodinophile vacuole. The shell-valves are relatively thick and exhibit two to seven or eight triangular markings in front view. When stained, two comparatively small nuclei without endosome are noticeable in the sporoplasm. Dimensions of spores: length and width 8-9  $\mu$ , thickness 4.5-5.5  $\mu$ , polar capsules 3-4  $\mu$  by 1.5-2  $\mu$ .

**REMARKS.**—Of the seventy species of *Myxobolus* (Kudo, 1933) two species—*M. transovalis* Gurley 1893 and *M. squamae* Keysselitz 1908—occur under the scales of fresh-water fish. These two species differ from the species under description in the major characters of the spore. The spores of *M. mülleri* Bütschli and *M. exiguum* Thélohan (Kudo, 1920) resemble those of the present species. But the vegetative form of the species under consideration is entirely different from that of either of the two species mentioned above.

*Myxobolus teres* n. sp.

(Figs. 64-67)

**HABITAT.**—In the body muscle of the silver fin, *Notropis whipplii*. From the Rock River near Milan (September 22, 1927). The fish, 3 cm. long and preserved in formol, showed an elongated ellipsoidal tumor on the left side of the body directly above the anal fin. The whitish tumor measured 3 mm. by 1.5 mm. and was located parallel to the lateral line. No other cysts were recognized.

**VEGETATIVE FORM.**—Sections cut at right angles to the body surface showed that the tumor was caused by a single cyst situated in the muscular tissue. It measured 1.75 mm. long and about 0.7 mm. deep. It was in direct contact with the muscle fibers, which showed no noticeable histological changes. Nuclei and disporoblastic pansporoblasts were located, as usual, close to the surface of the cyst, while young and mature spores were scattered throughout the reticulated cytoplasm. Polysporous.

**SPORE.**—Subspherical in front view; lenticular in side and end views. The shell is uniformly thick and as a rule smooth, although occasionally four or five oblong thickenings are present along the posterior margin. The sutural ridge is conspicuous, but the sutural line is indistinct. Two polar capsules are large, pyriform, and convergent. The sporoplasm is relatively small, but contains a very large iodinophile vacuole. In stained

spores the two nuclei of the sporoplasm are very distinct. Dimensions of spores: length 9.5-11.5  $\mu$ , breadth 9-10.5  $\mu$ , thickness 5-6  $\mu$ , polar capsules 6 by 3  $\mu$ .

*Myxobolus ovatus* n. sp.

(Figs. 68-71)

**HABITAT.**—In the integument of the small-mouth buffalo, *Ictiobus bubalis*. A fish, 6 cm. long, obtained from the Rock River near Rockford (September 22, 1928), and another, 18 cm. long, examined at a fish market in Havana (August 28, 1930), were infected by the present myxosporidian.

**VEGETATIVE FORM.**—The smaller fish had an indistinctly outlined and compressed cyst, measuring 1.5 by 1 mm., which was situated about one centimeter back of the posterior end of the gill-cover on the left lateral line. The larger fish had a somewhat more distinct cyst, measuring 2 by 1 mm., near the right ventral fin. In both fishes the cyst was surrounded by the connective tissue of the corium and contained mainly mature spores and a small number of developing disporoblastic pansporoblasts. Polysporous.

**SPORE.**—Oval with somewhat bluntly pointed anterior end in front view; lenticular in side view. The shell-valves are comparatively thin, and in many spores there are two or three thickenings on the posterior margin. The two polar capsules are equal or only slightly different in size, and the inner walls are arranged parallel to each other. The sporoplasm, which does not fill the remaining part of the intrasporal cavity, contains a conspicuous iodinophile vacuole. When stained, two nuclei, each with a small endosome, become clearly visible. Dimensions of spores: length 11.5-13  $\mu$ , breadth 9-10  $\mu$ , thickness 7  $\mu$ , polar capsules 5.5-6.5  $\mu$  by 2.5-3  $\mu$ .

*Myxobolus angustus* n. sp.

(Figs. 10, 20, and 72-75)

**HABITAT.**—In the gills of the bullhead minnow, *Cliola vigilax*, collected from the Illinois River at Meredosia Bay (June 18, 1928). Three specimens, 2.2 to 2.8 cm. in length and preserved in formol, had several clustered cysts on the gills which could be plainly seen through the operculum.

**VEGETATIVE FORM.**—The cysts were located in the gill filaments, which were much enlarged. Surrounded by flattened epithelial cells, these cysts were ellipsoidal in general form and varied in size from 150 by 6  $\mu$  to 260 by 100  $\mu$ . All cysts were at advanced stages of development, and

filled with mature spores and developing disporoblastic pansporoblasts. Polysporous.

**SPORE.**—Pyriform. The sutural ridge is distinct, but the sutural line indistinct. The shell is relatively thin, and shows a somewhat rough surface at the posterior margin, which stains deeply. Two polar capsules are elongated pyriform and equal or nearly equal in size. The sporoplasm is comparatively small and has a large iodinophile vacuole. When stained, the two nuclei are most often found in a point close to the posterior ends of the capsules. Dimensions of spores: length 14-15  $\mu$ , breadth 7-8  $\mu$ , thickness 6-7  $\mu$ , polar capsules 8-9.5  $\mu$  by 2.5-3  $\mu$ .

*Myxobolus vastus* n. sp.

(Figs. 76-81)

**HABITAT.**—In the corium above the scales of the common redhorse, *Moxostoma aureolum*. From the Fox River near Dundee (August 12, 1930). A large fish, 31 cm. long, showed three whitish tumors on the left side of the body. These tumors were ellipsoidal or circular in form, measured 3 by 1.5 by 1 mm., 4.2 by 2 by 2 mm., and 1 mm. in diameter by 0.5 mm. high, and were situated in the integument above the scales. Microscopical examination revealed that each tumor was composed of a single cyst surrounded by a thick envelope of the host tissue.

**VEGETATIVE FORM.**—In section preparations of the first two tumors, it was noted that the epidermis above the parasites was much thinned at places, while the connective tissue around them was greatly hypertrophied and was penetrated by a large number of anastomosing blood vessels and capillaries. The cysts were smoothly and distinctly outlined and measured 2.5 mm. and 3.8 mm., respectively, in the largest diameter. The homogeneous peripheral zone of cytoplasm was narrow, and the pansporoblasts, which were disporoblastic, were comparatively small in number, while an enormous number of spores occupied the greater central portion. Polysporous.

**SPORE.**—Oblong in front view; narrowly lenticular in side view. The shell is moderately thick and exhibits in many spores some seven radiating lines on the posterior margin. The sutural ridge is somewhat thickened at the ends, but the line is indistinct. Two polar capsules are pyriform, and the capsulogenous nuclei seem to remain for some time after the spore has matured. The sporoplasm is granulated and contains a large iodinophile vacuole. When stained, it shows two comparatively small nuclei. Dimensions of spores: length 9.5-10.5  $\mu$ , width 7.5-8  $\mu$ , thickness 4-4.5  $\mu$ , polar capsules 4.5-5.5  $\mu$  by 1.5-2.5  $\mu$ .

*Myxobolus gravidus* n. sp.

(Figs. 82-84)

**HABITAT.**—In the integument and fins of the white-nosed sucker, *Moxostoma anisurum*. From the Fox River near Carpentersville (August 14, 1930). One specimen, 11 cm. long, showed three cysts: two on the base of the tail fin and one on the left pectoral fin. The second fish, 12 cm. long, exhibited six cysts: three on the sides of the head and three on the ventral side of the body between the pectoral fins. All cysts were rounded and measured less than 0.5 mm. in diameter.

**VEGETATIVE FORM.**—The myxosporidian was studied in smears only, and therefore the exact seat of infection and the cytological detail of the cysts are unknown. However, it was observed that the pansporoblasts were disporoblastic. Polysporous.

**SPORE.**—Oval to oblong in front view; broadly fusiform in side or end view. The shell is moderately thick, with four to six folds on the posterior part. The sutural ridge is inconspicuous. Two polar capsules are pyriform and convergent. The sporoplasm is relatively large and contains an iodinophile vacuole and ordinarily two nuclei with a large endosome. Dimensions of spores: length 12-14  $\mu$ , width 9.5-10  $\mu$ , thickness 7  $\mu$ , polar capsules 5-5.5  $\mu$  by 2.5  $\mu$ .

*Myxobolus compressus* n. sp.

(Figs. 13 and 85-88)

**HABITAT.**—In the connective tissue of the integument of the straw-colored minnow, *Notropis blennius*. From the Rock River near Beloit (May 3, 1927). Six infected fishes, 4 to 4.5 cm. long, were preserved in formol. One fish was also infected by *Thelohanellus notatus*. To the unaided eye the body surface appeared uneven and the scales were somewhat lifted, so that the host fish presented a very characteristic appearance (Fig. 13). Unlike other *Myxobolus* cysts, individual cysts were indistinctly outlined.

**VEGETATIVE FORM.**—Examination of the sections of the integument revealed that enormous numbers of trophozoites were located in the connective tissue of the corium above and below the scales, which condition is without doubt responsible for the peculiar external appearance of the diseased fish. These vegetative forms were circular to irregularly rounded in surface view and extremely flattened, so that two or three or even five such trophozoites were situated one above the other between the scale and the epidermis. The host cells which were in direct contact with the myxosporidian body became much distended and the protoplasmic contents were apparently absorbed by the parasite, while the cell wall persisted, which resulted in the radiating cytoplasm along the periphery in

the trophozoite of the present myxosporidian. These cysts varied in size and measured from 300 to 600  $\mu$  in the largest diameter and about 50 to 100  $\mu$  thick, tapering gradually toward the periphery. They appeared somewhat like the trophozoites of coelozoic Myxosporidia such as *Zschokkella aceilognathi* (Kudo, 1920), and were very different from the *Myxobolus* cysts ordinarily met with. In the reticulated cytoplasm of the cyst were found numerous nuclei, developing sporoblastic pansporoblasts, and spores. Polysporous.

SPORE.—Ovoid to broadly ellipsoid in front view; broadly spindle-form in side view. The shell is uniformly thick, and exhibits about six small triangular markings along the posterior margin. The sutural ridge is moderately wide, with a distinct sutural line. One of the peculiar characteristics of this myxosporidian is the persistence of the capsulogenous cells and their nuclei, both of which remain visible long after the maturing of the sporoplasm. The granulated sporoplasm is relatively large and contains a large iodinophile vacuole and two nuclei filled with fine chromatin granules. Dimensions of spores: length 12-14  $\mu$ , width 7-10  $\mu$ , thickness 7-7.5  $\mu$ , polar capsules about 5 by 2.5  $\mu$ .

*Myxobolus mutabilis* n. sp.

(Figs. 11, 12, and 89-93)

HABITAT.—In the integument of the head and fins of the blunt-nosed minnow, *Pimephales notatus*. From the Rock River near Beloit (May 2 and 3, 1927). Seventeen fishes were preserved in formol. The distribution of the cysts upon the bodies of the hosts is shown in the accom-

Fish		Number of the Cysts	
Number	Length (cm.)	In Head	In Other Parts
1.....	3.8	32	
2.....	3.6	24	
3.....	4.3	4	3 on base of the left pectoral fin
4.....	4.5	36	1 near the left pectoral fin
5.....	3.8	8	25 on ventral and pectoral fins
6.....	4.0	22	2 on the right pectoral fin
7.....	4.0	17	1 on the left pectoral fin
8.....	6.3	30	3 near the right pectoral fin
9.....	6.0	19	12 on pectoral fins
10.....	5.0	23	9 on pectoral fins
11.....	4.5	33	
12.....	4.0	10	
13.....	4.2	6	
14.....	4.6	16	
15.....	4.7	8	
16.....	4.2	9	
17.....	5.0	12	

panying tabulation. The head region was most frequently infected. Infection of the eye was noticed only in one fish (No. 13). The pectoral fins were also often the seat of infection. The cysts were small, measuring less than 1 mm. in diameter. To the naked eye they appeared as small white spots. They were circular or oval in outline, but when grouped they presented very irregular contours.

**VEGETATIVE FORM.**—The cysts occurred in the connective tissue of the corium. In sections cut at right angles to the host's body surface, they were ellipsoidal in form, with their long axis lying parallel to the body surface, and varied somewhat in size, measuring from 450 by 150  $\mu$  to 880 by 250  $\mu$ . The peripheral zone of the cytoplasm, about 5  $\mu$  in thickness, was finely reticulated, while the remaining part was vacuolated. As is usually the case, numerous nuclei, generative cells, and sporoblastic pansporoblasts were confined to the peripheral portion, while mature spores occupied the central area of the cyst. Polysporous.

**SPORE.**—Greatly variable in form and size. Typically ellipsoidal with somewhat narrowed anterior half in front view; lenticular in side view. Some spores are, however, nearly spherical. A great variation of form was recognized among spores occurring in one and the same cyst. The shell is relatively thin and smooth. Along the suture of the shell-valves occurs a ribbon-like band encircling the spore. The edge of each valve is thickened so that there appear in profile three ridges on the spore. A similar structure had been noted by Balbiani in *Myxobolus ellipsoïdes* (Kudo, 1920). The two polar capsules are elongate pyriform and comparatively large. The large sporoplasm contains an iodinophile vacuole and two rather large nuclei. Dimensions of spores: length 9.5-12  $\mu$ , breadth 7.5-9  $\mu$ , thickness 6-7  $\mu$ , polar capsules 5-6.5  $\mu$  by 2-3.5  $\mu$ .

*Myxobolus nodosus* n. sp.

(Figs. 94-96)

**HABITAT.**—In the integument of the blunt-nosed minnow, *Pimephales notatus*. From the Rock River near Byron (August 22 and 23, 1927). Twelve fishes, preserved in formol, measured from 2 to 3.5 cm. in length. The myxosporidian produces small isolated cysts, which were especially abundant on the ventral side of the posterior half of body. They were smoothly rounded in outline and measured from 0.5 to 1 mm. in diameter.

**VEGETATIVE FORM.**—The nearly spherical cysts were lodged in the connective tissue of the corium. The host tissue around the cysts was moderately thickened and the epithelial tissue above the parasites somewhat thinned. Within the cyst there was noted, as is usually the case, a

thin homogeneous peripheral zone of cytoplasm containing numerous nuclei, generative cells, disporoblastic pansporoblasts at various stages of development, and mature spores. Polysporous.

**SPORE.**—Circular to subcircular in front view; broadly fusiform in side or end view. The shell is uniformly thin, except the posterior one-fourth which shows numerous rounded thickenings, presenting an undulating outline. The sutural ridge is broad and prominent, but sutural line indistinct. Two polar capsules are equal in size and relatively large and broadly pyriform. The sporoplasm is consequently small and contains an iodinophile vacuole. Dimensions of spores: length 9-10.5  $\mu$ , breadth 8.5-9.5  $\mu$ , thickness 7  $\mu$ , polar capsules 5-6  $\mu$  by 2.5-3.5  $\mu$ .

*Myxobolus obliquus* n. sp.

(Figs. 23, 24, and 97-101)

**HABITAT.**—In the body muscle fibers of the silver carp, *Carpoides velifer*. From the Rock River below Beloit (August 20, 1926; May 20, 1927) and the Illinois River at Meredosia (September 3, 1930). Two fishes from the first locality, 3.5 and 4 cm. long, were preserved in formol. Both specimens showed numerous obliquely directed white bodies embedded somewhat deeply on the sides of the body. Viewed with the naked eye, the smaller fish showed 29 and 18 such bodies on the right and left sides of body, respectively; while the larger fish showed 24 cysts, of which 9 were on the right and 15 on the left side of body. One of three fishes caught in the second locality, 5.5 cm. long, exhibited 5 and 9 cysts on the right and left sides, respectively.

**VEGETATIVE FORM.**—The cysts are situated in the host's muscle fibers. They are fusiform in general shape and circular in cross-section, measuring 500  $\mu$  to 1.8 mm. in length by 60 to 250  $\mu$  in diameter. The infected muscle fiber does not show any cytological changes other than an enormous increase in size as the parasite grows. The adjacent fibers appear to be perfectly normal. The cyst is distinctly and smoothly outlined and in direct contact with the host's cell body. The peripheral cytoplasm is granular and contains nuclei, generative cells, and developing pansporoblasts which are disporoblastic. Sporulation was advanced very far in all cysts examined, so that the interior of the cysts was vacuolated and occupied by numerous spores. Polysporous.

**SPORE.**—Circular or subcircular in front view; lenticular in side or end view. The shell is moderately thick, with five to ten radiating thickenings on it. The sutural ridge is narrow, but the line distinct. Two equal polar capsules are relatively large and convergent. In some spores there

is a small intercapsular projection. The sporoplasm occupies about one-half the cavity of the spore. The iodinophile vacuole is conspicuous. Each of the two nuclei of the sporoplasm contains an eccentric endosome. Dimensions of spores: length 8-9  $\mu$ , breadth 7-8  $\mu$ , thickness 5-6  $\mu$ , polar capsules 4.5 by 2  $\mu$ .

*Myxobolus bellus* n. sp.

(Figs. 22 and 102-105)

**HABITAT.**—In the integument of the common river carp, *Carpoides carpio*. From the Kaskaskia River near Carlyle (August 24, 1929). A small portion of the integument taken from one side of the body was preserved in formol.

**VEGETATIVE FORM.**—A single cyst, 1.8 by 1.2 mm., was lodged in the connective tissue of the integument. The pansporoblast is disporoblastic. Polysporous.

**SPORE.**—Ellipsoidal or elongate oval in front view; asymmetrically lenticular in side view. The shell is relatively thick and shows regularly three spinous markings near the posterior end. The shell-valves are somewhat asymmetrical. Two polar capsules are comparatively small. The finely granulated sporoplasm contains an iodophile vacuole. When stained, the capsulogenous nuclei are recognizable long after the spore has matured. The sporoplasm is binucleated. Dimensions of spores: length 10-11  $\mu$ , breadth 6.5-7  $\mu$ , thickness 4-5  $\mu$ , polar capsules 4-5  $\mu$  by 1.5-2  $\mu$ .

*Myxobolus congesticius* n. sp.

(Figs. 7, 14, 25, and 106-110)

**HABITAT.**—On the fins of the white-nosed sucker, *Moxostoma anisurum*. From the Fox River near Dundee (August 12, 1930). Of the thirty-five fishes, varying in length from 20 to 30 cm., twenty were infected by this myxosporidian which produced large conspicuous tumors on, or near the base of, the tail or anal fin of the host fish. These tumors measured 3 to 12 mm. long, 1 to 10 mm. wide and 1 to 6 mm. high, and were creamy white in life covered by a red network, which presented a quite typical appearance. On account of the highly distended condition of the tumors, the host's epidermis above the tumors was exceedingly thin and broke easily upon application of a slight pressure, setting free the creamy contents, which were almost exclusively made up of spores.

**VEGETATIVE FORM.**—The tumors were located in the subepidermal connective tissue, and each was made up of a large number of cysts. The

latter varied in form from spherical to irregularly angular—which seemed to be caused by fusion of two or more cysts and further by the pressure received from adjacent individuals—and measured 300  $\mu$  to 1 mm. in the largest diameter. These cysts were so closely associated with one another that only narrow spaces remained between them, and in these spaces were located blood vessels of various dimensions and tissue cells of the host. This condition accounts for the characteristic network on the tumor visible to the unaided eye. Variable in size and form, all cysts showed a similar structure. The outer surface of the cyst was sharply delimited from the host's tissue. Along the periphery there was a uniformly thick (8 to 15  $\mu$ ) homogeneous cytoplasmic zone in which no special structures were noticeable. Towards the central portion the cytoplasm was much vacuolated and contained numerous nuclei, generative cells, and sporoblastic pansporoblasts. Polysporous.

**SPORE.**—Circular or oval in front view; lenticular in side or end view. The shell is moderately thick and in many cases possesses fine radiating folds or markings which are visible in front view. The sutural ridge is wide and conspicuous, but the line indistinct. Two polar capsules are pyriform and convergent. In the sporoplasm is located a relatively large iodinophile vacuole. The sporoplasmic nuclei are often observed in unstained condition. They are frequently closely associated with each other in the direction at right angles to the sutural plane. Abnormal spores occur in this species as in others. One spore for example showed a single polar capsule in its normal position, while the other polar capsule appeared to be lodged in the shell, which may be due to an early development of the polar capsules in the present species. Dimensions of spores: length 9-10  $\mu$ , breadth 8.5-9.5  $\mu$ , thickness 6  $\mu$ , polar capsules 5-6  $\mu$  by 2.5-3.5  $\mu$ .

*Myxobolus conspicuus* Kudo

(Figs. 15 and 16)

This myxosporidian was first observed in the short-headed redhorse, *Moxostoma breviceps*, collected from the Rock River at Rockford in November and December, 1925 (Kudo, 1929). It was found further in twelve out of twenty-three fishes of the same species seined in the Fox River near Dundee (August 12 and 13, 1930). It produces conspicuous cysts in the integument of the head of the host. Vegetative forms and spores have already been described (Kudo, 1929), and no additional information except its occurrence was obtained by the study of recent material.

*Myxobolus aureatus* Ward

(Figs. 9, 26-28, and 111-115)

**HABITAT.**—In the fins of the blunt-nosed minnow, *Pimephales notatus*. This myxosporidian was first observed in a specimen, 2.5 cm. long, caught in Lake Decatur (July 30, 1929). One of the fishes collected from the Rock River near Sterling (August 19, 1930) was also infected by it. Of many fishes, collected from the Fox River in the vicinities of Carpentersville, St. Charles, and Johnsburg (July 30 to August 20, 1930), eighty-four specimens, 1.9 to 3.8 cm. long, were heavily infected by the same protozoan. All fins were subject to infection, but pectoral and ventral fins were in most cases most frequently and heavily attacked. Of these paired fins there was no noticeable difference in intensity of infection between the two sides. The number of cysts occurring on various fins of individual fishes varied from 2 to 63, although in the majority of the fishes 4 to 15 cysts were commonly encountered. The one fish caught at Sterling showed yellow-colored cysts as was noted by Ward (Kudo, 1920). All other fishes were preserved in formol. The cysts were opaque, white, and very conspicuously visible to the naked eye because of their location on the fins. One of the characteristics of these cysts is the presence of numerous enlarged chromatophores scattered through the host tissue surrounding them. The larger cysts were oblong, ovoid, or ellipsoid and measured from 0.5 to 1 mm. in the largest diameter, while the smaller cysts were as a rule nearly spherical and measured from 0.1 to 0.3 mm. in diameter, being almost invisible to the unaided eye.

**VEGETATIVE FORM.**—The cysts are spherical or ellipsoidal in cross-section. When several cysts occur together, they assume various forms due to the mutual pressure. The largest diameter of the cysts varied in cross-section from 100 to 1000  $\mu$ . The cysts are located in the connective tissue of the fins, in which a far greater number of blood capillaries occur than in healthy tissue. This is probably responsible for the striking abundance and hypertrophy of chromatophores around the cysts. Except for a narrow peripheral zone, all of the cysts were vacuolated and filled with developing and mature spores. The pansporoblast is disporoblastic. Polysporous.

**SPORE.**—Pyriform with bluntly pointed anterior and broadly rounded posterior ends. The sutural ridge is narrow but distinct; the line also is distinct. The posterior portion of each shell-valve is slightly constricted near the sutural ridge. In some spores there are seen two narrow ridges running from the latero-posterior margin to a point near the center of the spore. Two polar capsules, which are equal or slightly different in size, are comparatively long and show plainly their coiled filaments. The sporoplasm is finely granulated and contains an iodinophile vacuole and

two nuclei which are often recognizable in unstained conditions. Dimensions of spores: length 12-14.5  $\mu$ , breadth 7-8  $\mu$ , thickness about 7  $\mu$ , polar capsules 8-10  $\mu$  by 2.5-3  $\mu$ .

REMARKS.—There are slight differences in size of spores and cysts, and in the host species, between the form described above and *Myxobolus aureatus* Ward from Lake Erie. They are, however, too small to consider the present form as a new species.

*Thelohanellus notatus* (Mavor)

(Figs. 116-118)

The genus *Myxobolus* comprises, as set forth by Thélohan in his classification, the *Myxosporidia* with tailless spores, each containing an iodinophile vacuole and one or two polar capsules. In a recent paper (Kudo, 1933) it was proposed to separate the unicapsulated species from the bicapsulated forms, and there was established a new genus, *Thelohanellus*, to which all unicapsulated *Myxobolus* were transferred, and *Myxobolus* was retained for bicapsulated species. Accordingly *Myxobolus notatus* Mavor is now designated as *Thelohanellus notatus* (Mavor).

HABITAT.—This myxosporidian was hitherto observed in the bluntnosed minnow, *Pimephales notatus*, from the waters of North America (Kudo, 1929). Examination of material on hand shows that it occurs also in several other species of fishes in Illinois. Two specimens of this minnow caught in the Rock River near Sterling (August 19, 1930) harbored the protozoan. One fish had a white cyst, 2 mm. in diameter, on the ventral side of the head. The cyst was situated within the connective tissue of the integument. The other fish had two cysts, both about 1.5 mm. in diameter, near the dorsal fin on the right side of the body. They were also located in the subepidermal connective tissue.

The bullhead minnow, *Cliola vigilax*. From the Rock River (June, 1925). In a single fish preserved in formol, a tumor was noted on the anterior left side of the body. It was oblong in outline and measured 5 mm. in the largest diameter. This tumor was due to the presence of a large cyst located in the hypertrophied subepidermal connective tissue.

The common shiner, *Notropis cornutus*. Near Rockford (August 18, 1930). In one fish a large tumor, 7 mm. in the longest diameter and raised 3 mm. above the general body surface, was recognized just behind the head on the left side. In sections, an almost spherical cyst was found within the tumor, which was surrounded by a thick layer of subepidermal connective tissue of the host fish, containing a large number of blood vessels and capillaries.

The straw-colored minnow, *Notropis blennius*. Rock River near Beloit (May 3, 1927). Of three fishes, preserved in formol, one had two cysts: one on the dorsal side just in front of the dorsal fin and the other on the right side near the anal fin. The second fish showed one cyst situated on the base of the right pectoral fin. The third fish exhibited two cysts: one on the left side near the tail fin and the other below the dorsal fin on the right side of the body. The seat of infection was the same as that mentioned above.

VEGETATIVE FORM.—The cysts were surrounded by the connective tissue of the integument of the host fish. The host tissue which was in direct contact with the parasite underwent a peculiar change as noted before (Kudo, 1929). The cytological observation of the cysts did not yield any new data.

SPORE.—The spores taken from cysts occurring in the four different host species are indistinguishable from one another. Elongated pyriform, but often broadly pyriform which are obviously not fully mature. A slight variation in size is noted in the cysts taken from the same or different fishes. The sporoplasm is large and occupies about one-half of the intrasporal cavity. An iodinophile vacuole is very prominently present in the sporoplasm. Dimensions of spores: length 14-17  $\mu$ , breadth 7-8  $\mu$ , thickness 5.5-6.5  $\mu$ , polar capsules 6-7 by 3  $\mu$ .

*Henneguya clavicauda* n. sp.

(Figs. 31 and 119-125)

HABITAT.—In the subdermal connective tissue of the straw-colored minnow, *Notropis blennius*. From the Rock River near Rockford (June 20, 1927). A single fish, 2.8 cm. long, preserved in formol, showed five cysts on the left side and three on the right side of the body. The whitish cysts were oblong or ellipsoid in form and measured from 1 to 1.5 mm. in the longest diameter.

VEGETATIVE FORM.—In cross-sections the cysts were ellipsoid with their long axis located parallel to the host body surface. The outer surface of the cyst was distinctly outlined. Along the periphery there was a granulated or finely reticulated zone of cytoplasm, about 5 to 10  $\mu$  wide, which was free from nuclei and which in places was radially striated. Internal to this zone, a coarsely vacuolated cytoplasmic area containing nuclei, granules, and sporoblastic pansporoblasts was noted. The remaining part was highly vacuolated and filled with scattered nuclei and spores. Polysporous.

SPORE.—Oval or oblong in front view; broadly spindle-form in side view. The shell is moderately thick. The sutural ridge is prominent, but

sutural line indistinct. Certain spores show three to six thickenings or markings around the posterior half. The characteristic posterior appendage is a single club-shaped body. It measures 20 to 30  $\mu$  long, although shorter ones less than 10  $\mu$  in length are also met. The anterior end of this appendage expands into a cup-like structure which fits closely the posterior part of the spore. It is circular in cross-section. The appendages of some spores appear to be composed of a homogeneous substance and possess a smooth surface except the posterior end where a constriction often occurs; others are made up of bands of somewhat varying diameters and present a beaded appearance. These conditions are noted both in preserved unstained and in stained spores. The shell and appendage do not show same coloration against same stain. With Giemsa the shell stains blue, the appendage rose-red; with Delafield hematoxylin and eosin, the shell remains almost unstained, while the appendage stains rose-red. Two polar capsules are nearly equal in size and convergent. The anterior halves of the capsules are parallel to each other. The sporoplasm contains a very large iodinophile vacuole and two small nuclei. Dimensions of spores: length 10.5-11.5  $\mu$ , breadth 8.5-9.5  $\mu$ , thickness 6  $\mu$ , posterior appendage 20-30  $\mu$  by 3-6.5  $\mu$ , polar capsules 5-5.5  $\mu$  by about 2.5  $\mu$ , iodinophile vacuole 2-4  $\mu$  in diameter.

REMARKS.—There are 52 known species of the genus (Kudo, 1933). Of these *Henneguya macrura* Gurley (Kudo, 1920) shows certain features which resemble those of the present form. Comparison of dimensions and structure of both the spore and the vegetative form brings out too great a difference to consider them identical.

*Henneguya crassicauda* n. sp.

(Figs. 32-34 and 126-129)

HABITAT.—In the fins and integument of the stone-roller, *Campostoma anomalum*. The fish, 8 cm. long, was collected from a small creek near Rockford (August 18, 1930). The small ovoid cysts on fins were quite conspicuous to the unaided eye, although those on the body surface were visible only through a magnifier.

VEGETATIVE FORM.—In the fin, the seat of infection was the epidermis or the connective tissue below it. In the body proper, the cysts were situated in the subepidermal connective tissue. The cysts varied from 200 to 400  $\mu$  by 100 to 250  $\mu$ . The peripheral cytoplasmic zone appeared radially striated—a condition different from that seen in *Henneguya clavicauda* but similar to that observed in *Myxobolus compressus*. The greater portion of the cyst was occupied by spores which were embedded in highly vacuolated cytoplasm. The pansporoblast is disporoblastic. Polysporous.

SPORE.—Oval, oblong, or subcircular in front view; broadly fusiform in side view. The shell is moderately thick and smooth. The sutural line is fairly distinct; the ridge is prominent. There is a characteristic posterior appendage which is independent of the shell. Its anterior end expands into a cup-like form and fits closely the posterior margin of the spore. This condition is similar to that found in *H. clavicauda*. It is broadest at the anterior end and tapers gradually to a bluntly pointed posterior end. It is approximately circular in cross-section at any point. In an unstained spore the appendage is less refractive than that of the last-named species, although distinctly recognizable. In a few spores the appendage was bifurcated. Staining brings about a differentiation between the shell and appendage similar to that stated for the last species. Two polar capsules are large, pyriform, and convergent, extending about to the middle of the intrasporal cavity. The sporoplasm fills the posterior half of the spore and is finely granulated. The iodinophile vacuole is very large and the two nuclei are highly vesicular. Dimensions of spores: length 12-14.5  $\mu$ , breadth 8.5-10.5  $\mu$ , thickness 6-7  $\mu$ , posterior appendage 40-55  $\mu$  by 3.5-4.5  $\mu$ , polar capsules 5-6  $\mu$  by 3-3.5  $\mu$ .

*Henneguya exilis* Kudo

(Figs. 6, 29, and 30)

This myxosporidian was originally described from the gills of the channel cat, *Ictalurus punctatus*, collected from the Rock River at Sterling (Kudo, 1929). Since then the following additional data were obtained.

HABITAT.—Each of the two gill-arches of a channel cat collected from the Sangamon River near Decatur (August 21, 1929) showed six conspicuous cysts, which were subspherical and which measured from 2 to 3 mm. in diameter. Two fishes caught in the Fox River near Dundee (August 13, 1930) had several cysts of this protozoan in the gills (Fig. 6), and two out of twenty-nine fishes examined at a fish market in Havana (August 28, 1930) were also infected by this myxosporidian. Pieces of the integument of two fishes collected from the Kaskaskia River—one near Vandalia (August 17, 1929) and the other near Keyston (August 19, 1929)—contained several circular to irregularly outlined flattened cysts. They were preserved in Zenker's fluid. In the material from one fish 17 cysts were counted, while 12 cysts were observed in that of the other fish. These cysts were creamy white and measured from 1 to 2.5 mm. in diameter. In another fish, 18.5 cm. long, caught in Lake Decatur (August 29, 1929), five cysts were noticed in the integument. These cysts were circular in form and measured 3 to 4 mm. in

diameter. The spores of these integumental forms were indistinguishable from those of the branchial form.

VEGETATIVE FORM.—No additional information was obtained on the form occurring in the gills other than that which was already reported (Kudo, 1929). In the sectioned integument, it was found that the cysts were located in the subepidermal connective tissue. Observation on the structure of the cysts and morphological detail of the spore agrees very well with the published report. Hence these recent forms are placed under *Henneguya exilis*. All these rivers from which the infected fishes were collected are tributaries of the Mississippi River. Probably this myxosporidian is a common parasite of the channel cat of this river system.

### SUMMARY

1. The results of a preliminary study of fishes of Illinois belonging to thirty-five species with reference to their protozoan parasites are presented. These fishes belong to thirteen families, of which Catostomidae, Cyprinidae, and Siluridae were found to be common hosts to histozoic protozoan parasites.
2. An unusual case of *Ichthyophthirius* infection in carp is noted.
3. Nineteen new species of Myxosporidia are studied and described.
4. Additional information on four known species of Myxosporidia is given.

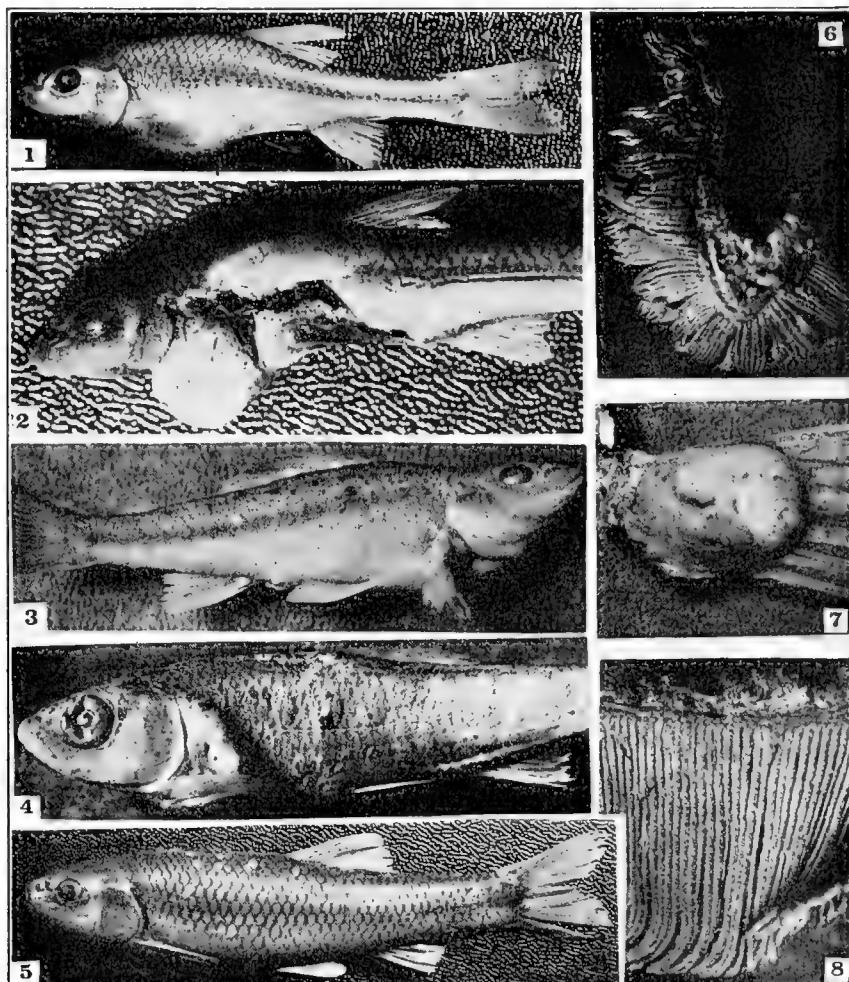
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## PLATE I

FIG. 1.—Silver-mouthed minnow, *Ericymba buccata*, showing the typical appearance due to a heavy infection of the liver by *Myxosoma grandis*.  $\times 8/10$

FIG. 2.—Silver-mouthed minnow with partly exposed viscera, showing the hypertrophied liver infected by *Myxosoma grandis*.  $\times 1.5$

FIG. 3.—Trout-perch, *Percopsis guttatus*, with the cysts of *Myxosoma procerum*.  $\times 1$

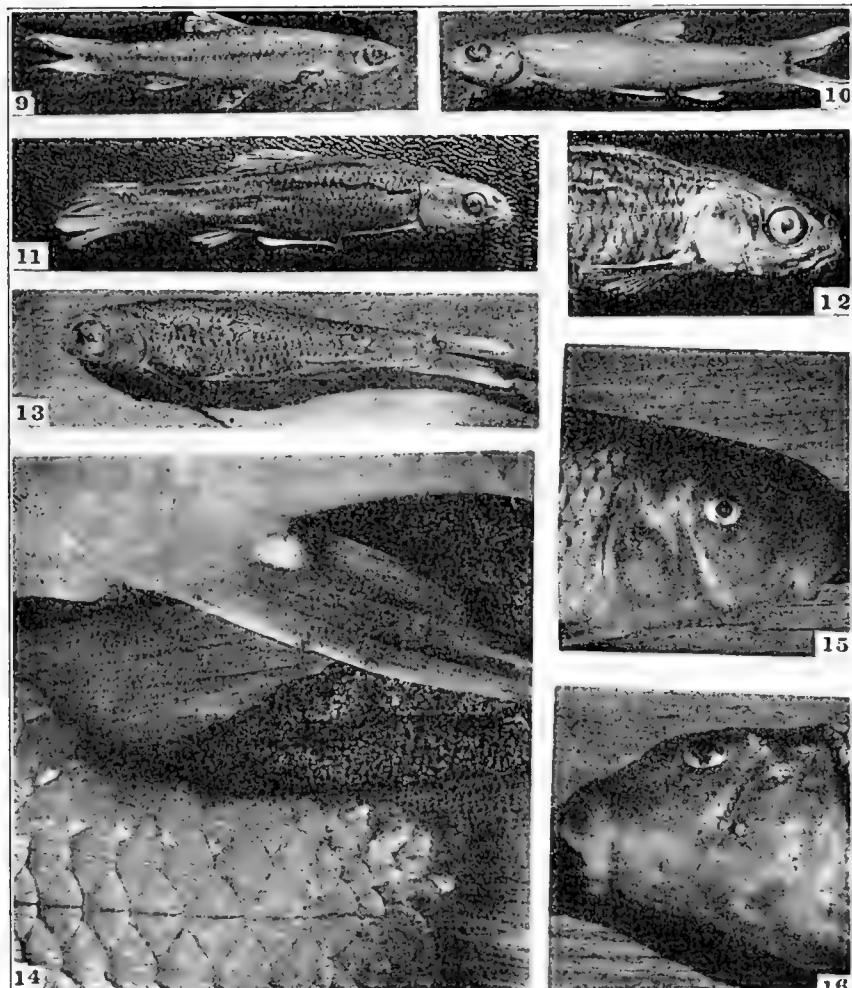
FIG. 4.—Common shiner, *Notropis cornutus*, with a large tumor produced by *Myxosoma robustum*.  $\times 1.5$

FIG. 5.—River chub, *Hybopsis kentuckiensis*, with cysts of *Myxobolus squamosus*.  $\times 3/4$

FIG. 6.—Gill of a channel catfish, *Ictalurus punctatus*, with cysts of *Henneguya exilis*.  $\times 1.5$

FIG. 7.—Part of the anal fin of a white-nosed sucker, *Moxostoma anisurum*, exhibiting a large tumor composed of cysts of *Myxobolus congesticus*.  $\times 1.5$

FIG. 8.—Portion of gill of a carp heavily infected by *Ichthyophthirius multifiliis*.  $\times 1.5$



## PLATE II

FIG. 9.—Blunt-nosed minnow, *Pimephales notatus*, with numerous cysts of *Myxobolus aureatus* on the fins.  $\times 1.5$

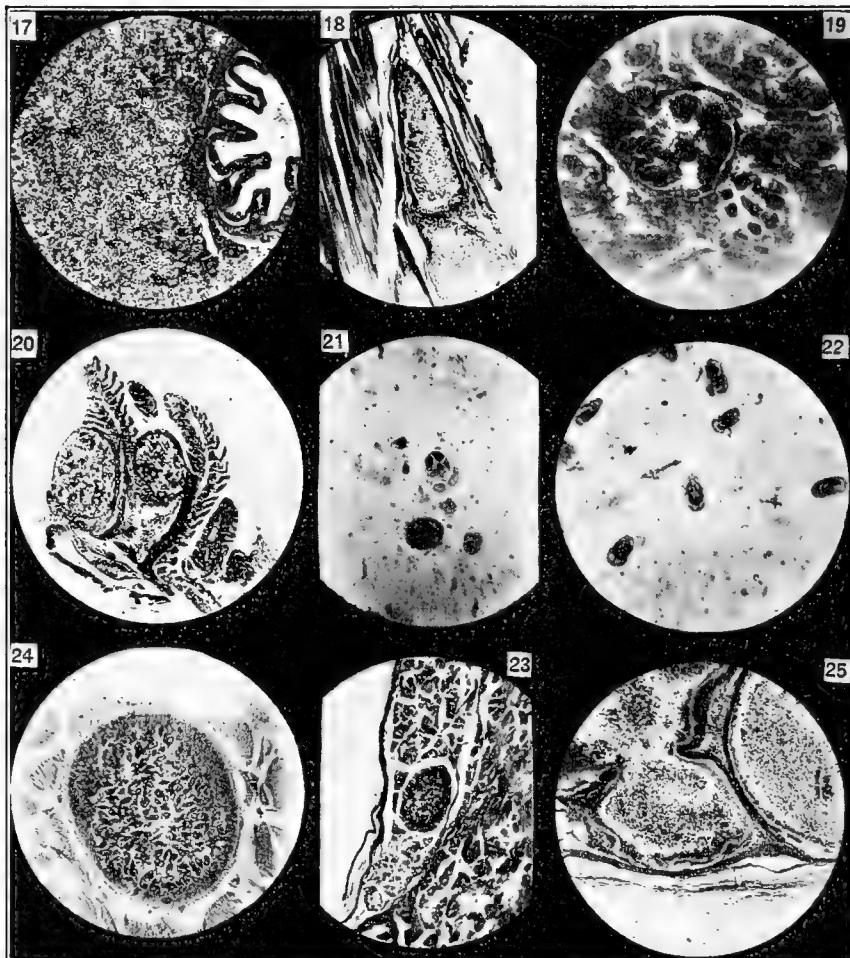
FIG. 10.—Bullhead minnow, *Cliola vigilax*, with part of its gill-cover removed, showing cysts of *Myxobolus angustus* in the gills.  $\times 1.5$

FIGS. 11 and 12.—Blunt-nosed minnows with the cysts of *Myxobolus mutabilis*.  $\times 1$  and  $\times 1.5$

FIG. 13.—Straw-colored minnow, *Notropis blennius*, showing the typical appearance of the integument due to a heavy infection by *Myxobolus compressus*.  $\times 1.5$

FIG. 14.—Parts of two white-nosed suckers, *Moxostoma anisurum*, showing tumors produced by *Myxobolus congesticulus*. The anal fin of the upper fish exhibits the typical appearance of a large tumor, while a smaller one is noticeable at the base of the caudal fin of the lower fish.  $\times 1.5$

FIGS. 15 and 16.—Two short-headed red horses, *Moxostoma breviceps*, showing cysts of *Myxobolus conspicuus*.  $\times 1/3$



## PLATE III

FIG. 17.—Part of a section of the viscera of *Ericymba buccata*, showing its liver heavily infected by *Myxosoma grandis*.  $\times 47$

FIG. 18.—Part of a section through the integument and muscles of *Percopsis guttatus*, showing two cysts of *Myxosoma procerum* in the connective tissue.  $\times 47$

FIG. 19.—Part of a similar section under higher magnification.  $\times 450$

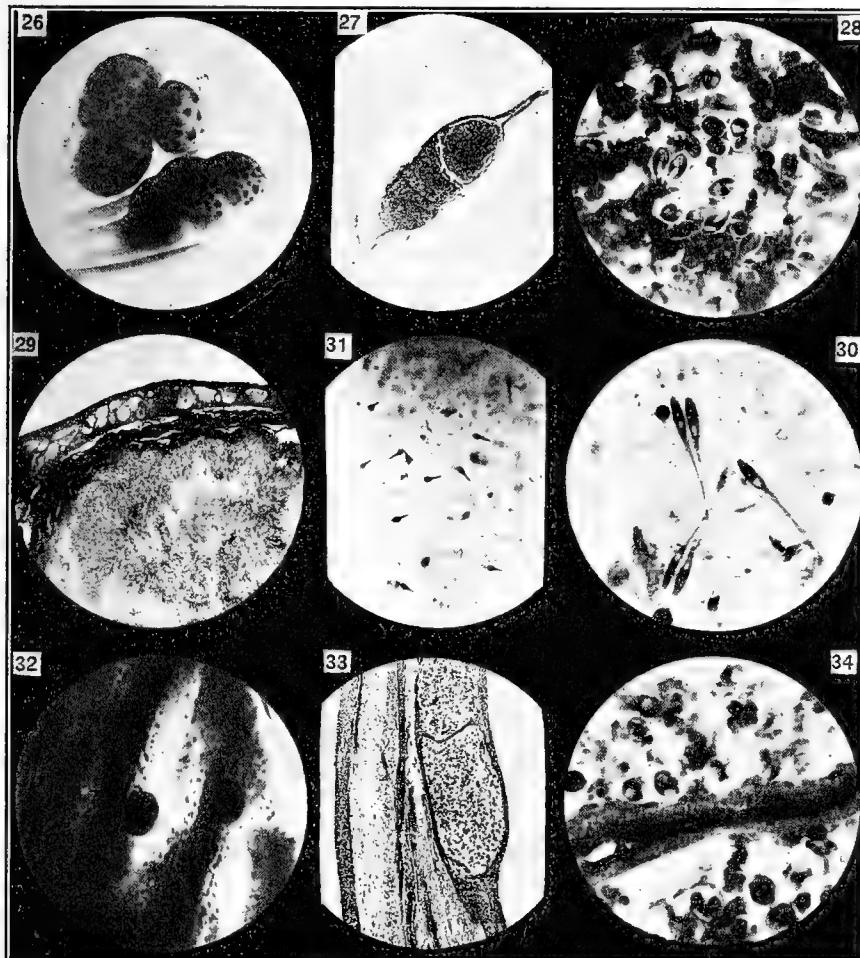
FIG. 20.—Part of gill of *Cliola vigilax* with cysts of *Myxobolus angustus*.  $\times 47$

FIG. 21.—Two Giemsa-stained spores of *Myxosoma bibullatum*.  $\times 450$

FIG. 22.—Delafield-stained spores of *Myxobolus bellus*.  $\times 450$

FIGS. 23 and 24.—Cross-sections of body muscles of *Carpoides velifer*, showing cysts of *Myxobolus obliquus*.  $\times 95$  and  $\times 230$

FIG. 25.—Portion of section of a tumor on the fin of *Moxostoma anisurum*, containing cysts of *Myxobolus congesticus*.  $\times 47$



## PLATE IV

FIG. 26.—A characteristic view of six cysts of *Myxobolus aureatus* on a pectoral fin of *Pimephales notatus*.  $\times 16$

FIGS. 27 and 28.—Cross-sections through cysts of the myxosporidian in a ventral fin of another fish of the same species.  $\times 16$  and  $\times 450$

FIG. 29.—Part of a section of the integument of *Ictalurus punctatus* with a cyst of *Henneguya exilis*.  $\times 47$

FIG. 30.—Stained spores of *Henneguya exilis* in a smear.  $\times 450$

FIG. 31.—Stained spores of *H. clavicauda* in a smear.  $\times 95$

FIG. 32.—Cysts of *H. crassicauda* in the fin of *Campostoma anomalum*.  $\times 16$

FIGS. 33 and 34.—Two cysts of *H. crassicauda* in section.  $\times 47$  and  $\times 450$

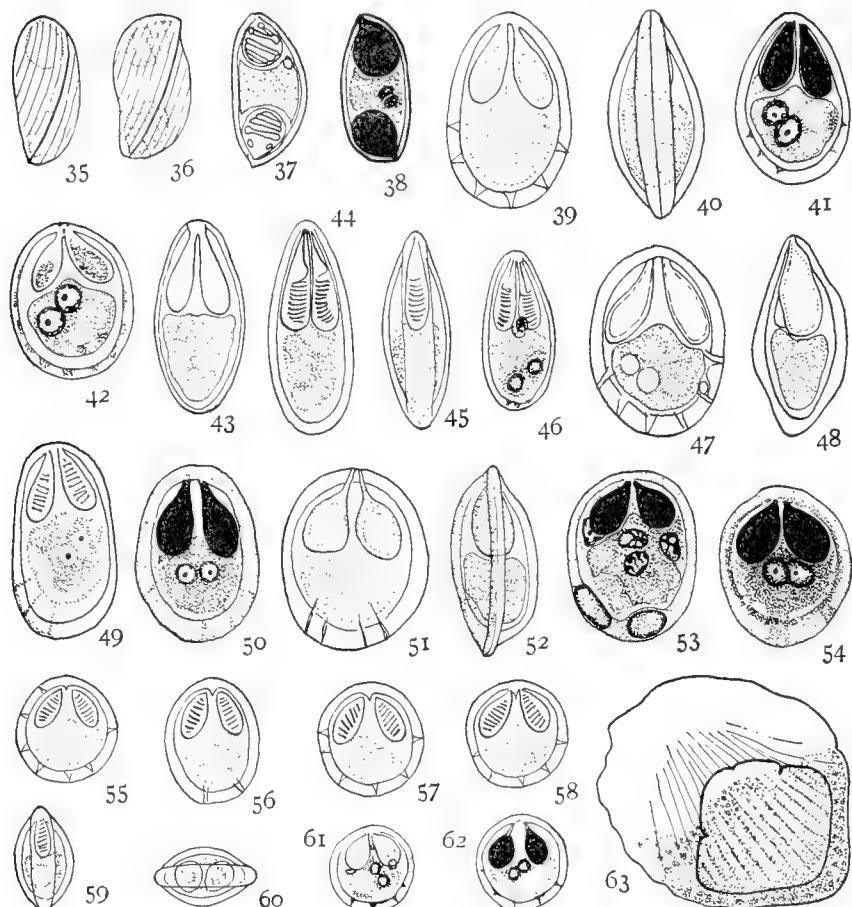


PLATE V

(All figures  $\times 1725$ , except Fig. 63)

FIGS. 35-38.—*Myxidium aplodinoti*: Figs. 35-37, fresh spores; Fig. 38, a Giemsa-stained spore.

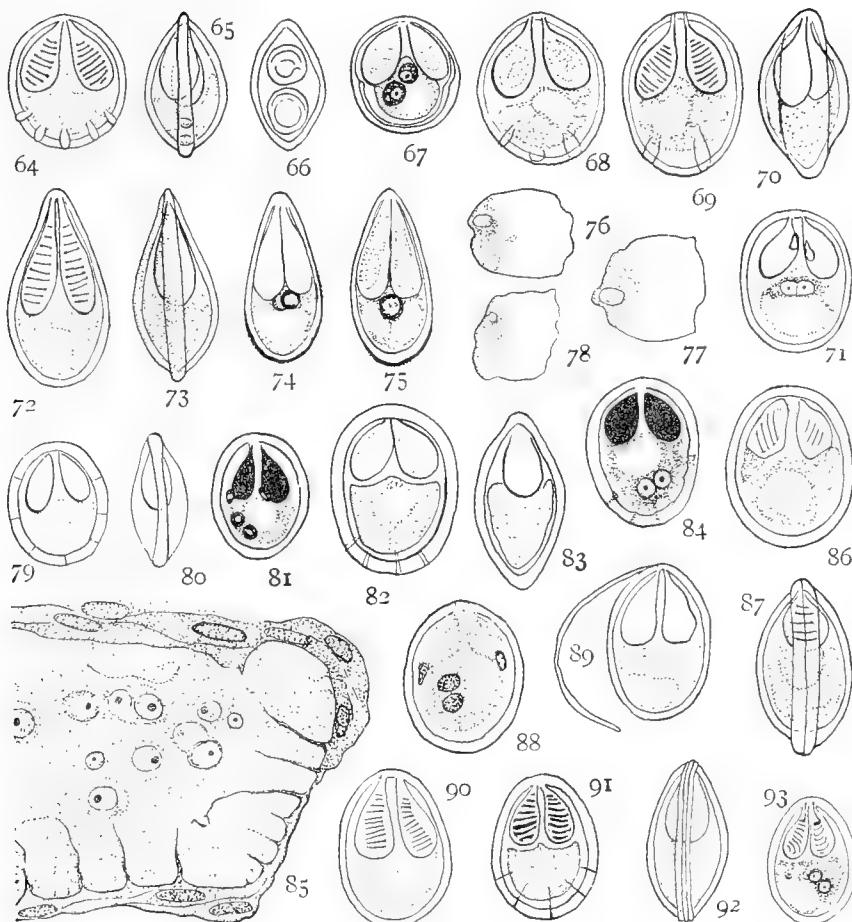
FIGS. 39-42.—*Myxosoma grandis*: Figs. 39 and 40, preserved spores in front and side views; Figs. 41 and 42, Delafield- and Giemsa-stained spores.

FIGS. 43-46.—*Myxosoma procerum*: Figs. 43 and 44, front views of preserved spores; Fig. 45, side view of a preserved spore; Fig. 46, a Delafield-stained spore.

FIGS. 47-50.—*Myxosoma robustum*: Fig. 47, front view of a preserved spore; Fig. 48, optical section of a preserved spore from side; Figs. 49 and 50, Heidenhain- and Giemsa-stained spores.

FIGS. 51-54.—*Myxosoma bibullatum*: Figs. 51 and 52, front and side views of preserved spores; Fig. 53, a young Giemsa-stained spore, shown in Fig. 21; Fig. 54, a Giemsa-stained spore.

FIGS. 55-63.—*Myxobolus squamosus*: Figs. 55-58, front views of preserved spores; Figs. 59 and 60, side and end views of preserved spores; Figs. 61 and 62, Heidenhain- and Giemsa-stained spores; Fig. 63, an infected scale of a river chub ( $\times 10$ ).



## PLATE VI

(All figures  $\times 1725$ , except Figs. 76-78)

Figs. 64-67.—*Myxobolus teres*: Figs. 64 and 65, front and side views of preserved spores; Fig. 66, anterior optical section view of a preserved spore; Fig. 67, a Delafield-stained spore.

Figs. 68-71.—*Myxobolus ovatus*: Figs. 68 and 69, front views of preserved spores; Fig. 70, side view of a preserved spore; Fig. 71, a Delafield-stained spore.

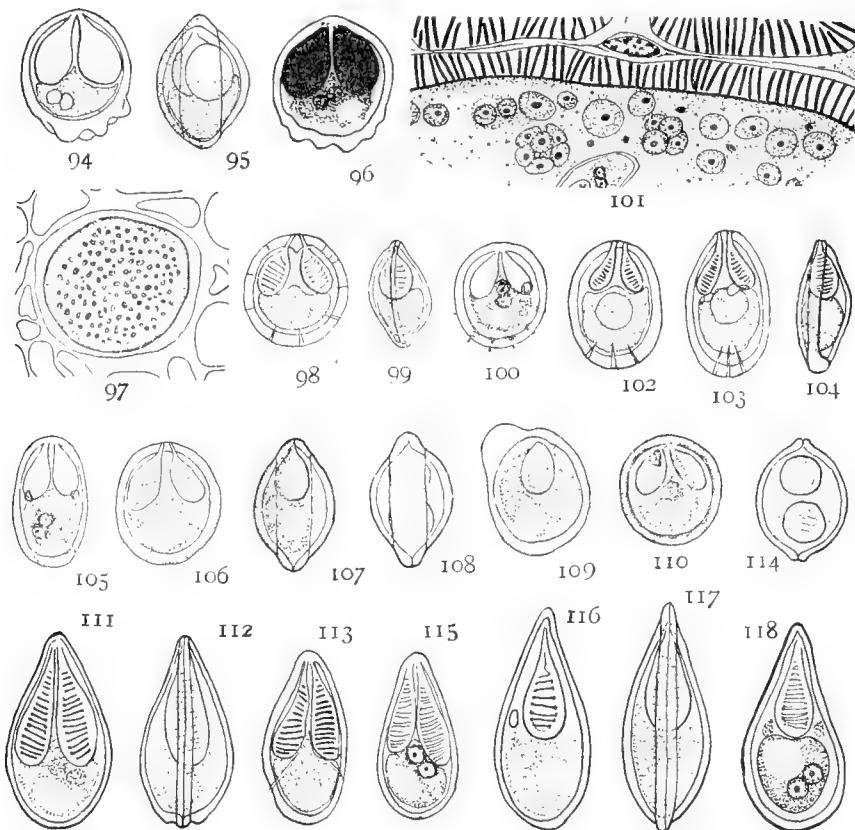
Figs. 72-75.—*Myxobolus angustus*: Figs. 72 and 73, front and side views of preserved spores; Figs. 74 and 75, Giemsa-stained spores.

Figs. 76-81.—*Myxobolus vastus*: Figs. 76-78, three scales of *Moxostoma aureolum*, each with a cyst of the myxosporidian ( $\times 2/3$ ); Figs. 79 and 80, front and side views of preserved spores; Fig. 81, a Giemsa-stained spore.

Figs. 82-84.—*Myxobolus gravidus*: Figs. 82 and 83, front and side views of preserved spores; Fig. 84, a Giemsa-stained spore.

Figs. 85-88.—*Myxobolus compressus*: Fig. 85, part of a section of a cyst and the host tissue; Figs. 86 and 87, front and side views of preserved spores; Fig. 88, a Delafield-stained spore.

Figs. 89-93.—*Myxobolus mutabilis*: Figs. 89-91, front views of preserved spores; Fig. 92, side view of a preserved spore; Fig. 93, a Heidenhain-stained spore.



## PLATE VII

(All figures  $\times 1725$ , except Figs. 97 and 101)

Figs. 94-96.—*Myxobolus nodosus*: Figs. 94 and 95, front and side views of preserved spores; Fig. 96, a Giemsa-stained spore.

Figs. 97-101.—*Myxobolus obliquus*: Fig. 97, a diagrammatic view of an infected muscle ( $\times 190$ ); Figs. 98 and 99, front and side views of preserved spores; Fig. 100, a Delafield-stained spore; Fig. 101, part of a cyst in section ( $\times 1300$ ).

Figs. 102-105.—*Myxobolus bellus*: Figs. 102 and 103, front views of preserved spores; Fig. 104, side view of a preserved spore; Fig. 105, a Delafield-stained spore.

Figs. 106-110.—*Myxobolus congesticius*: Figs. 106-108, front, side, and end views of preserved spores; Fig. 109, an abnormal spore; Fig. 110, a Delafield-stained spore.

Figs. 111-115.—*Myxobolus aureatus*: Fig. 111-114, preserved spores in different views; Fig. 115, a Delafield-stained spore.

Figs. 116-118.—*Thelohanellus notatus*: Figs. 116 and 117, preserved spores in front and side views; Fig. 118, a Delafield-stained spore.

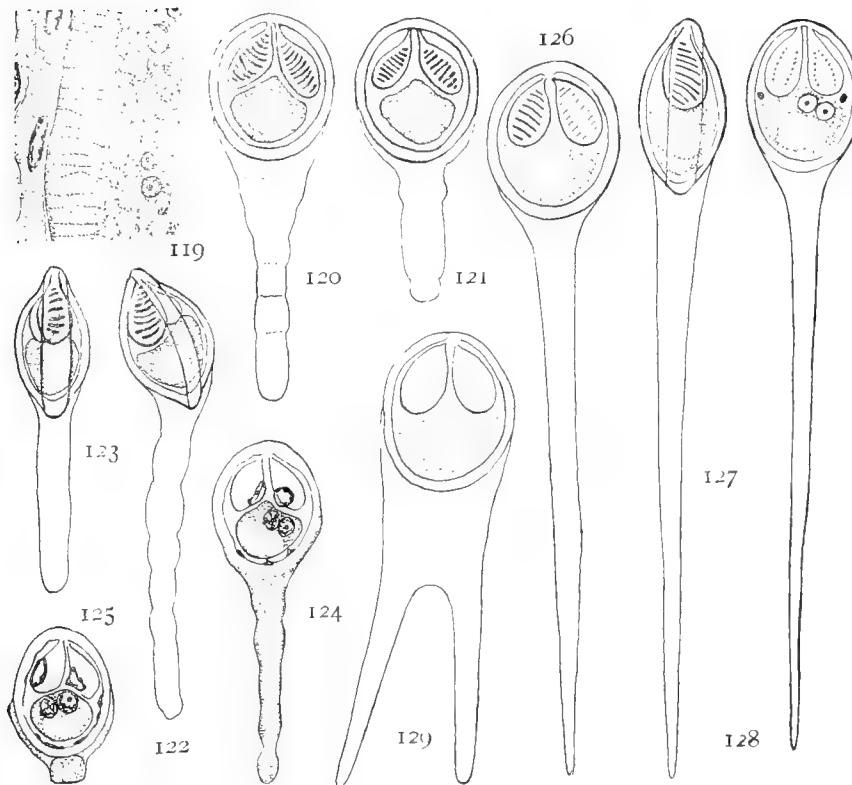


PLATE VIII  
(All figures  $\times 1725$ )

Figs. 119-125.—*Henneguya clavicauda*: Fig. 119, part of a section of a cyst and the host tissue; Figs. 120 and 121, front views of preserved spores; Figs. 122 and 123, side views of preserved spores; Figs. 124 and 125, Delafield-eosin-stained spores.

Figs. 126-129.—*Henneguya crassicauda*: Figs. 126 and 127, front and side views of preserved spores; Fig. 128, a Delafield-stained spore; Fig. 129, an abnormal spore with a bifurcated caudal prolongation.

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